

ADVANCES IN CHIMERA GRID TOOLS FOR MULTI-BODY DYNAMICS SIMULATIONS AND SCRIPT CREATION

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OVERVIEW

- > Framework for multi-body dynamics - Geometry Manipulation Protocol (GMP)
- > Dynamics simulation using Chimera Grid Tools (CGT) and OVERFLOW-2
- > Further recent developments in Chimera Grid Tools
 - OVERGRID
 - Grid modules
 - Script library
- > Summary and future work

MULTIPLE COMPONENT DYNAMICS

Motivation - Problem setup is difficult and not standardized

Objective - Develop solver-independent standard protocol
Make it easy to use

Approach

- Develop protocols and tools for describing
 - hierarchical relationship between static/moving components, grids, geometry, etc.
 - prescribed motion
 - 6-dof motion with external loads and constraints

Murman, S. M., Chan, W. M., Aftosmis, M. J., Meakin, R. L., 'An Interface for Specifying Rigid-Body Motions for CFD Applications', AIAA Paper 2003-1237, 41st AIAA Aerospace Sciences Meeting, Jan., 2003

GEOMETRY MANIPULATION PROTOCOL

Configuration

Each component may

- have one immediate parent or no parent
- move relative to the parent
- be linked to geometry or grids (structured/unstructured)
- have an initial transform (rotate/translate/mirror)

Scenario

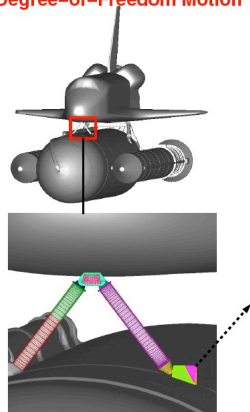
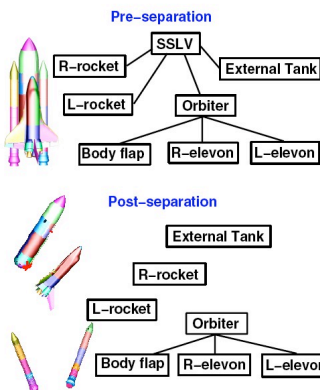
Motion of each component may be

- Prescribed** - sequence of rotate and translate commands that are analytic functions of time
- Aero6dof** - specified by
 - mass properties (mass, principal moments of inertia, and principal axes orientation)
 - initial location of center of mass
 - external loads and constraints (gravity, app. load, etc.)

EXAMPLES OF PRESCRIBED AND 6-DOF MOTION

Prescribed Motion

6-Degree-of-Freedom Motion



MULTI-BODY CFD SIMULATIONS (previous procedure)

- > Write special code for dynamics of each component
- > Determine how to interface with flow solver by
 - reading complicated documentation (if any)
 - talking to flow solver authors (if available)
- > Recompile flow solver
- > Verify and debug by running flow solver
- > Plot grids at different times to check dynamics

MULTI-BODY CFD SIMULATIONS (current procedure)

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Pre-processing using OVERGRID

- > Define components (hierarchy/grid links)
- > Specify and verify dynamics **before** running flow solver
 - animate prescribed motion
 - animate 6-dof motion by solving Newton's and Euler's equations of motion (zero aero loads assumed)
- > Write XML files for flow solver to read

Solution computation using OVERFLOW-2

- > Read XML files from OVERGRID for dynamics input
- > No code writing, recompilation or knowledge of flow solver interface needed

Post-processing using OVERGRID and OVERPLOT

- > Animate 6-dof motion of components
- > Animate scalar quantities with simple solution viewer
- > Plot component force/moment breakdown, residuals, etc.

CURRENT VALIDATED CAPABILITIES IN OVERFLOW-2

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- > Each component undergoes either prescribed or 6-dof motion for all time
- > Some components may have prescribed motion followed by 6-dof motion
- > Applied forces and moments for 6-dof motion are allowed to be functions of time
- > Simple constrained 6-dof motion is coded but not validated yet

VALIDATION TEST CASES FOR GMP DYNAMICS

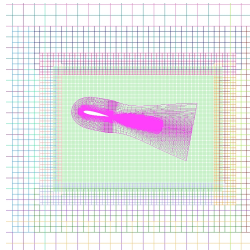
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Comparison with analytic solutions (aero-loads turned off)

- > Sphere dropped under gravity
 - initially at rest, with time varying resistive force
 - with initial upward velocity
- > Tumbling cylinder pinned at center of mass (no gravity)
 - with initial angular velocity

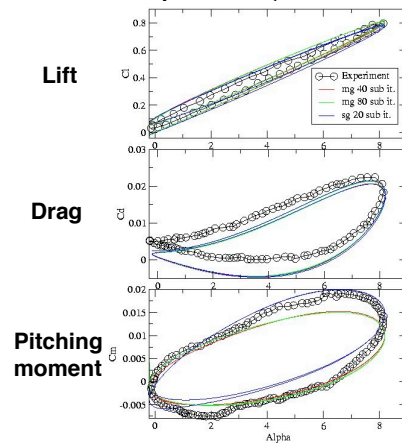
Comparison with experiments

- > Oscillating airfoil
 - prescribed motion, dual time step
 - $-0.2 \leq \alpha \leq 8.2$ (case 1)
 - $6.8 \leq \alpha \leq 15.2$ (case 2)
 - $10.8 \leq \alpha \leq 19.2$ (case 3)



OSCILLATING AIRFOIL TEST CASE 1

$-0.2 \leq \alpha \leq 8.2$, DTPHYS=0.157, 200 steps/cycle



Multiple-grid

- 40 sub-iterations
- 80 sub-iterations

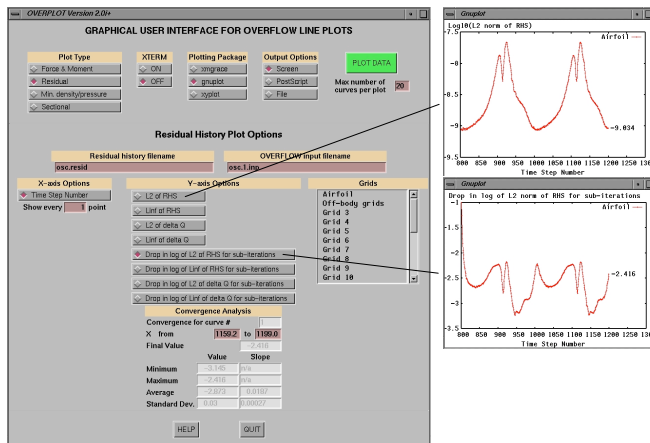
Single-grid

- 20 sub-iterations

Reference
Ko, S. and McCroskey, W. J.,
Computations of Unsteady
Separating Flows over an
Oscillating Airfoil,
AIAA Paper 95-0312, 1995.

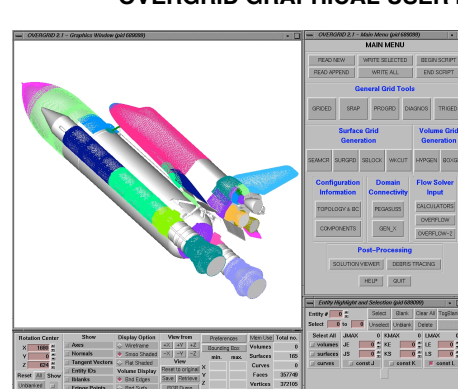
OVERPLOT POST-PROCESSING INTERFACE RESIDUALS PANEL

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OVERGRID GRAPHICAL USER INTERFACE

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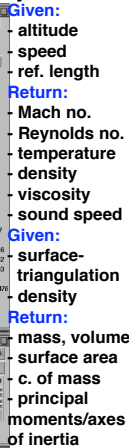


Capabilities

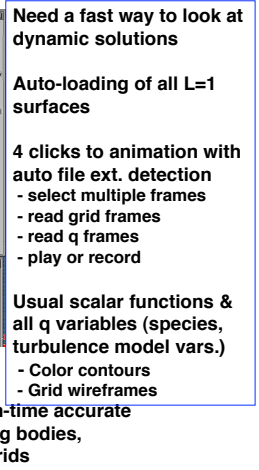
- Geometry processing (structured panels, triangulations)
- Grid processing, redistribution, projection
- Surface and volume grid generation (TFI, hyperbolic)
- Grid diagnostics
- Flow solver inputs and boundary conditions preparation
- Multiple components dynamics input and animation
- Atmospheric conditions and mass properties calculators
- Simple solution viewer
- Debris trajectory analysis

Supported platforms - Unix, Linux, Mac OS-X

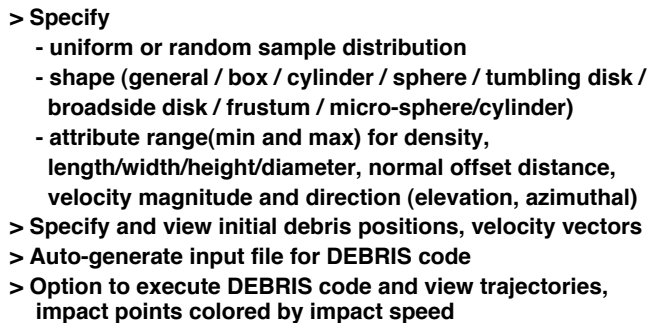
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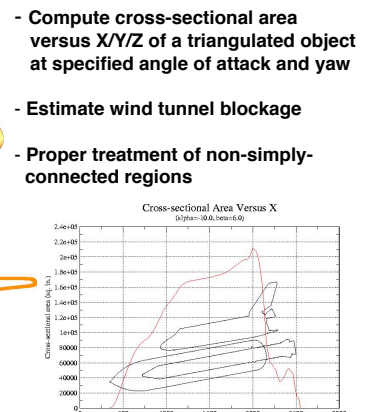
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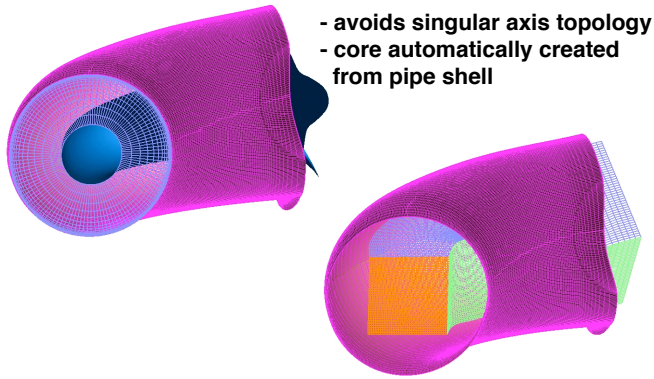


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PIPE CORE GRID GENERATION TOOL - GENCORE

Automatic generation of singularity-free volume grids inside varying-diameter pipe



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CGT SCRIPT LIBRARY DEVELOPMENT

- > Macro Tcl procedures for grid generation script creation
- > Factor of 10 or more compact scripts
- > Factor of 3 or more faster in script development

Library procedures

- File manipulation (e.g., combine files, ...)
- Grid information (e.g., interrogate dimensions, grid coordinates, arc lengths, ...)
- Grid editing (e.g., extract, concatenate, split, duplicate, swap/reverse indices, translate, rotate, revolve, ...)
- Grid redistribution
- Grid generation (e.g., TFI surface, hyperbolic and Cartesian volume, ...)
- Math functions
- OVERFLOW namelist i/o
- Program execution and error checking

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CGT SCRIPT LIBRARY EXAMPLES

```
set id { open grided.i w }
puts $id "in.dat"
puts $id " 1 1 ITIN,ITOUT"
puts $id " 1 MOP"
puts $id " 1 NGSO"
puts $id " 5"
puts $id " 11 IOP"
puts $id " 1 -1 1 JS,JE,JI"
puts $id " 1 1 KS,KE,KI"
puts $id " 1 1 LS,LE,LI"
puts $id " 0 IYN"
puts $id " 1 IYN"
puts $id " 1 MOP"
puts $id " 1 NGSO"
puts $id " 17"
puts $id " 11 IOP"
puts $id " 1 -1 1 JS,JE,JI"
puts $id " 1 -1 1 KS,KE,KI"
puts $id " 1 1 LS,LE,LI"
puts $id " 0 IYN"
puts $id " 1 IYN"
puts $id " 9 MOP"
puts $id "out.dat"
puts $id " 2 NWRITE"
puts $id " 5, 17"
puts $id " 0 IYN"
close $id
exec $File(GRIDED) < grided.i >& grided.o
```

Extract K=1 curve of grid 5 and entire grid 17 from file *in.dat* and write result to *out.dat*

→ ExtractSubs *in.dat out.dat* \ [list 5 1 -1 1 1 1] [list 17]

Redistribute surface grid from file *in.sur* for all points in J direction with

- max stretching ratio of Sr
- end spacings of Ds1 and Ds2
- max spacing no larger than Dsmax
- number of points that will allow 3 levels of multi-grid

and write result to *out.sur*

StrapRedist *in.sur out.sur 1 J 1 5 3* \ [list 1 -1 \$Sr \$Ds1 \$Ds2 \$Dsmax]

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CGT SCRIPT LIBRARY APPLICATIONS

N-STAGE LIQUID ROCKET SUB-SYSTEMS

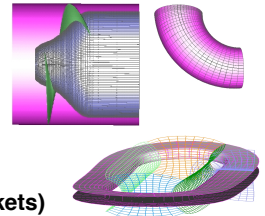
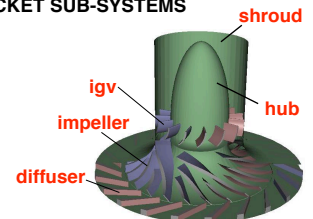
Objectives

Develop script system to automatically generate

- grids
- hole-cutting X-ray maps
- domain connectivity inputs
- flow solver inputs

Capabilities

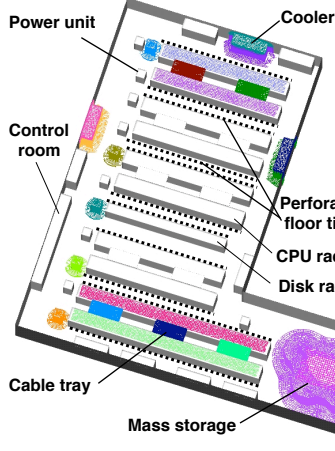
- component modules for
 - blade (inducer, inlet guide vanes, impeller, diffuser)
- ring (hub to shroud section)
- pipe (shroud only)
- nose (hub end)
- flowliner (bellows, valves, slots)
- strut assembly (hub, vanes, brackets)



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CGT SCRIPT LIBRARY APPLICATIONS

COMPUTER ROOM AIR FLOW SIMULATION



Developed script to create

- geometry
- viscous overset surface and volume grids
- boundary conditions, domain connectivity, and flow solver inputs

Parameterized inputs for

- room dimensions
- protuberance sizes and coordinates

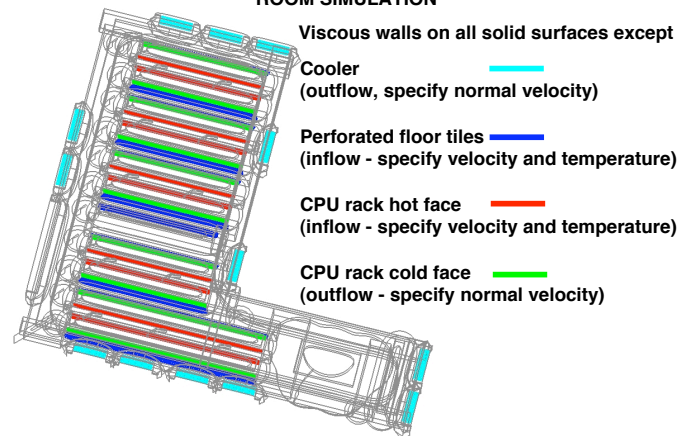
Script created in about 3 man days

12 million points
102 grids

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CGT SCRIPT LIBRARY APPLICATIONS

SCRIPT-GENERATED BOUNDARY CONDITIONS FOR COMPUTER ROOM SIMULATION



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SUMMARY

Tool suite (OVERGRID, OVERFLOW-2, OVERPLOT)

- developed for rapid, easy-to-use multi-body dynamics CFD simulations
- includes grid generation, input preparation, flow computation, dynamics animation, simple flow visualization, history plots of residuals, forces, moments, dynamics data, etc.

Expanded script library in CGT

- simplifies grid generation script creation
- more compact scripts
- less development time

FUTURE WORK

Over 100 items in CGT development to-do list

Short term - driven by Return-To-Flight and unsteady liquid rocket sub-systems simulations

Medium term - CAPRI interface for grid generation on native CAD models

Long term - hybrid overset grid technology